



# NASA's STEREO Mission



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# *The STEREO Mission*

- Science and technology definition team report, 1997 December:
  - Understand the origin and consequences of coronal mass ejections (CMEs)
  - Two spacecraft in earth-leading and -lagging orbits near 1 AU (Solar Terrestrial Probe line)
  - “Beacon” mode for near-realtime warning of potentially geoeffective events





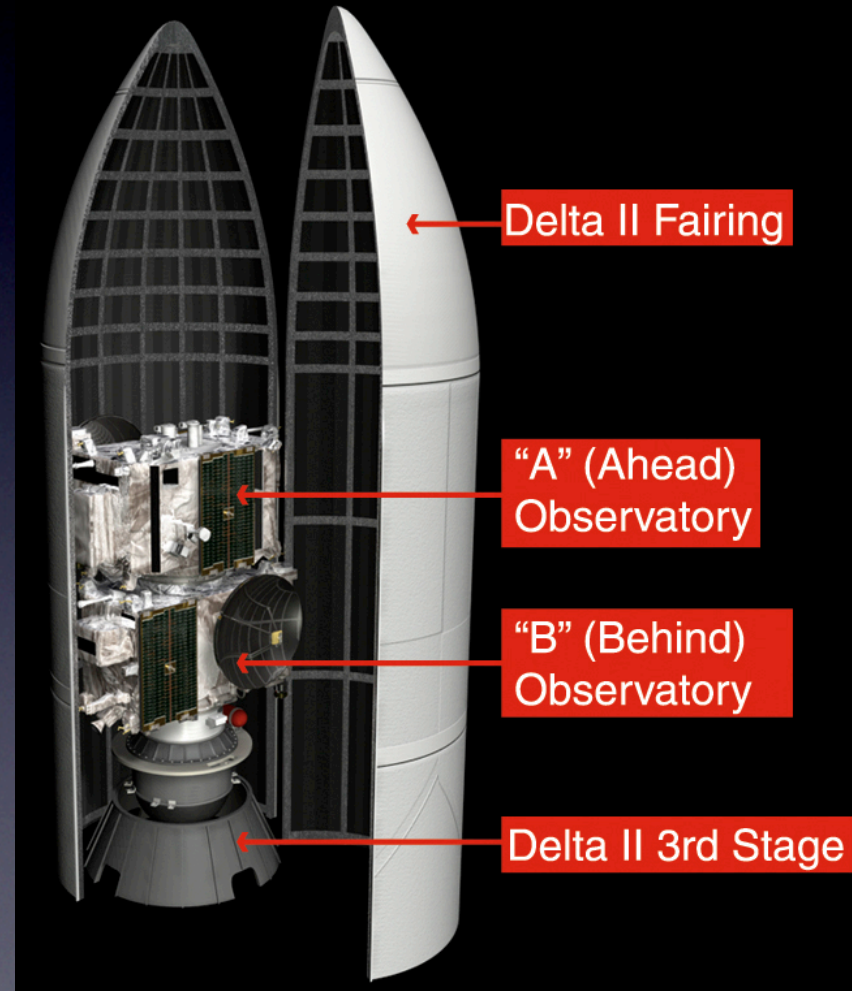
# *Level 1 Requirements*

- Understand the causes and mechanisms of CME initiation
- Characterize the propagation of CMEs through the heliosphere
- Discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium
- Develop a 3D, time-dependent model of the magnetic topology, temperature, density, and velocity structure of the ambient solar wind



# Implementation

- Two nearly identical spacecraft launched by a single ELV
- Bottom spacecraft in stack has adapter ring, some strengthening
- Spacecraft built at Johns Hopkins University APL
- Four science investigations





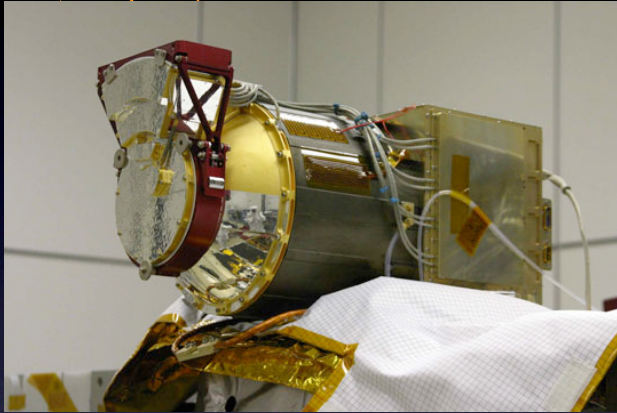


# *Scientific Instruments*

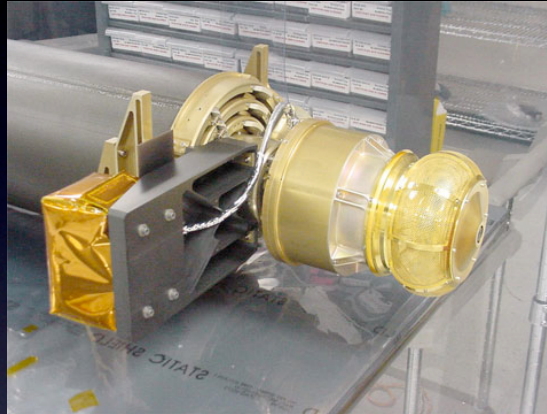
- S/WAVES - broad frequency response RF detection of Type II, III bursts
- PLASTIC - solar wind plasma and suprathermal ion composition measurements
- IMPACT - energetic electrons and ions, magnetic field
- SECCHI - EUV, coronagraphs and heliospheric imagers (surface to 1.5 AU)



# *Instrument Hardware*



PLASTIC



IMPACT boom



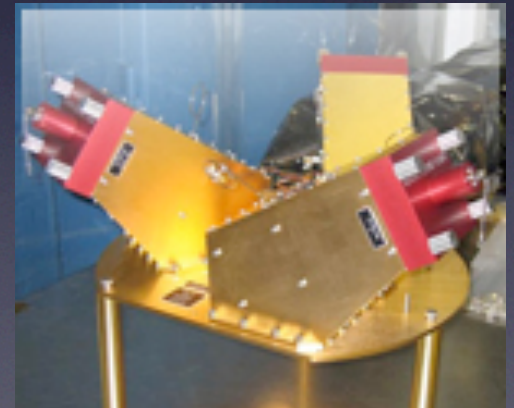
IMPACT boom



SECCHI SCIP



SECCHI HI



S/WAVES





# *Orbit Design*

- Science team selected a separation rate of  $22^\circ \text{ year}^{-1}$  from the Sun-earth line
- Implemented by launching the spacecraft into slightly different phasing orbits with apogees beyond the moon's orbit
- Use moon for gravity assist to achieve heliocentric orbits with desired separation rate



# *Launch and Transfer*

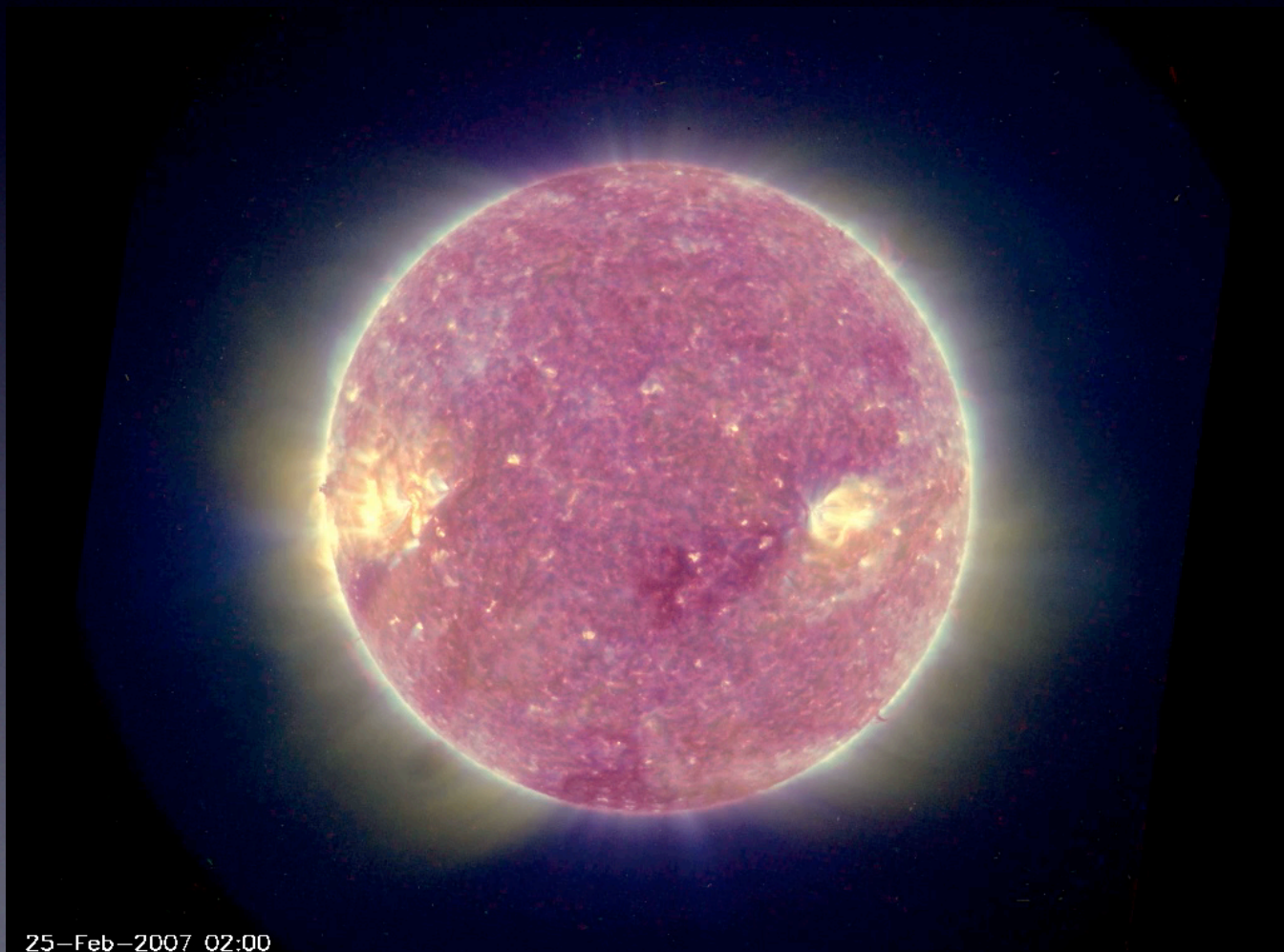
- Spacecraft launched 2006 October 25 (26 UT)
  - Delta II 7925-10L from CCAFS
- Ahead spacecraft transferred to heliocentric orbit 2006 December 22
- Behind in heliocentric orbit 2007 January 21
- To see where STEREO A and B are today, use:
  - <http://stereo-ssc.nascom.nasa.gov/where.shtml>





# *A unique view (during early heliocentric ops)*

- Lunar transit of the Sun,  
2007  
February 25



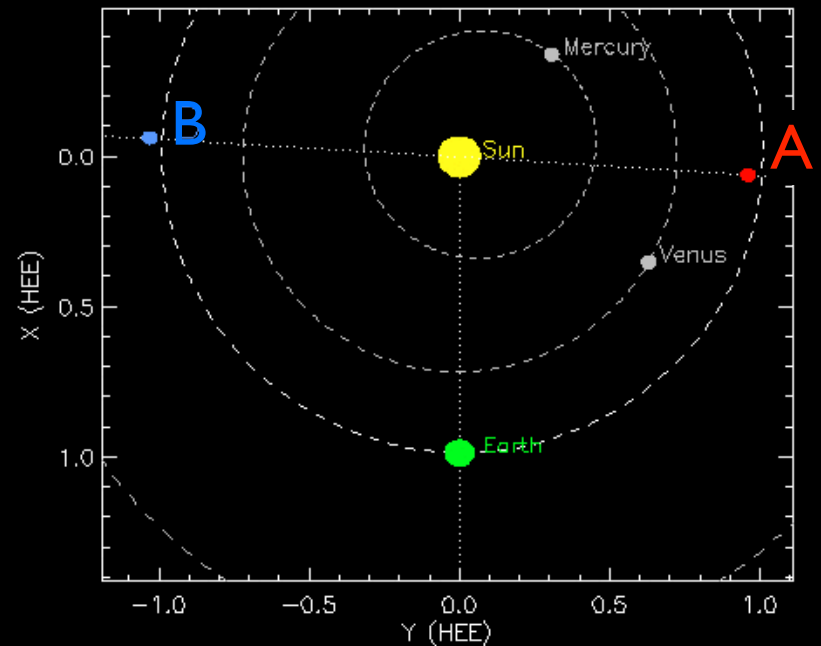
25-Feb-2007 02:00



# An Aside

- Question: What will happen on 2011 February 6 at 7:30 PM CST?
- Super Bowl XLV
- STEREO spacecraft will be in opposition

Positions of STEREO A and B for 2011-02-07 01:30 UT







# *Space Weather Information from STEREO (I)*

- Beacon mode
  - Low rate (633 bps)
  - Informal antenna partners
    - Arranged in partnership with NOAA SWPC
    - Currently: Bochum and Kiel (radio *amateurs* in Germany), Toulouse, France (CNES), Koganei, Japan (NIISC)
    - Don't quite span the globe: need more!
      - Large gap between 139°E and 7°E
      - Need site(s) in Pacific, mainland US



# *Beacon mode data availability*

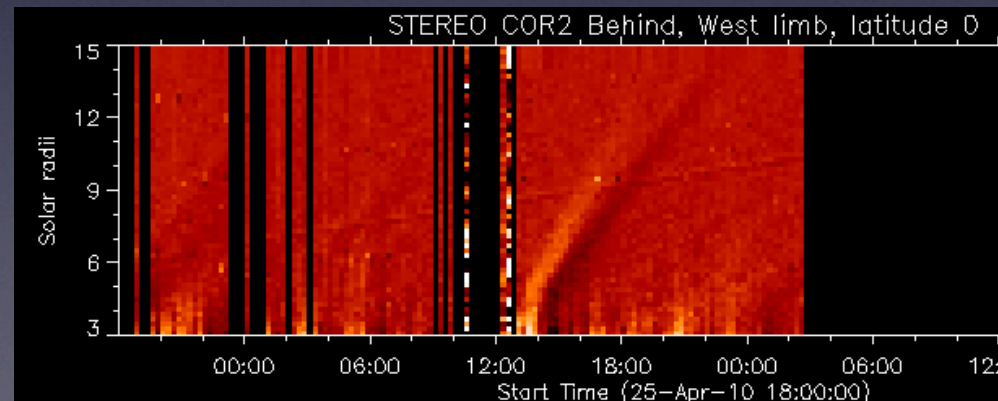
- Like all STEREO data, under the NASA Heliophysics Data Management Policy, the beacon mode data are publicly available as soon as they hit the ground and are reformatted ( $< 5$  min.)
- from the STEREO Science Center (SSC)
- Images
  - <http://stereo-ssc.nascom.nasa.gov/browse/>
- *In situ* and radio
  - <http://stereo-ssc.nascom.nasa.gov/browse/insitu.shtml>





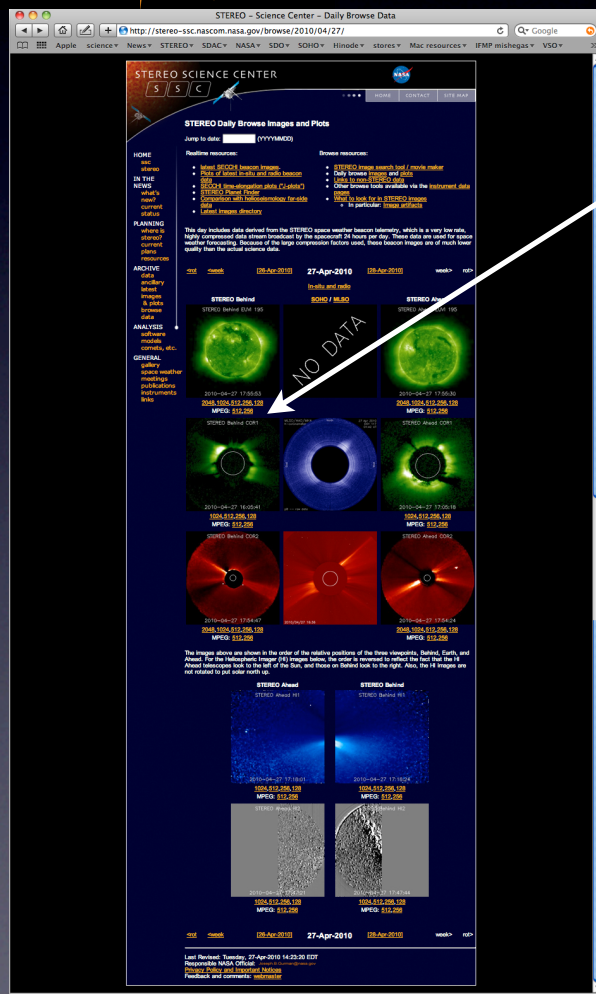
# *What do we get in beacon mode?*

- SECCHI images reduced to 256 x 256 pixels and mercilessly compressed
- Subsampled solar wind and energetic particle data (PLASTIC, IMPACT)
- Subsampled RF data from S/WAVES
- Links to higher level beacon-mode products, such as “J-plots”





# Beacon mode data

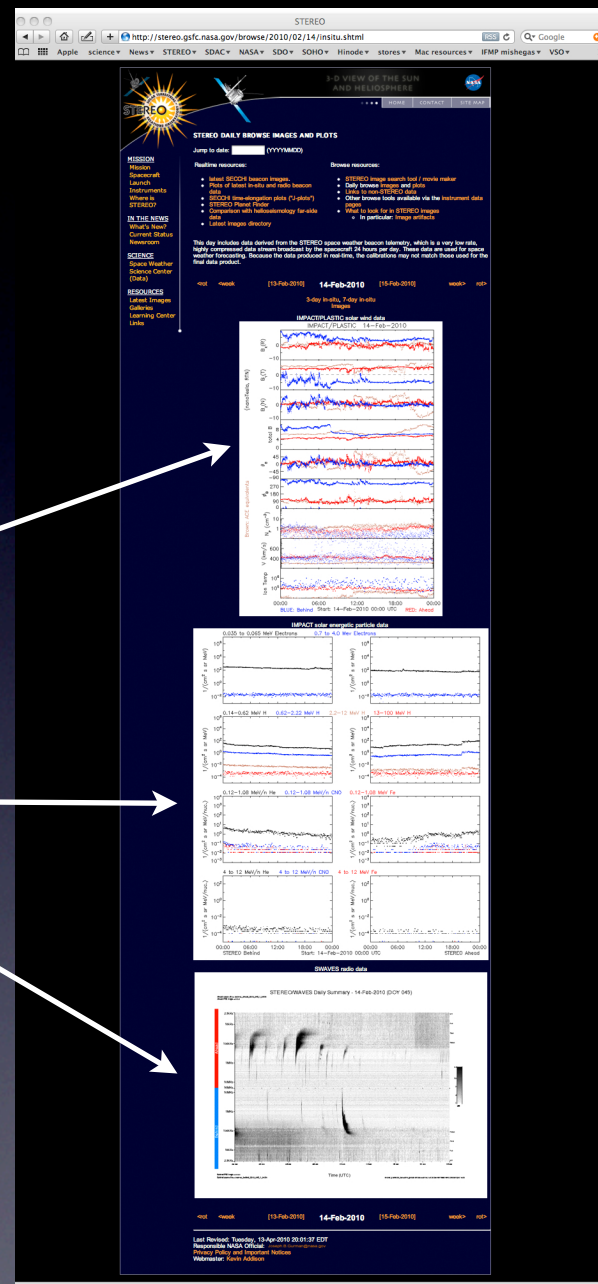


Images, links to movies

Solar wind plasma and magnetic field data

Energetic particles

RF data (2.5 kHz - 16 MHz)



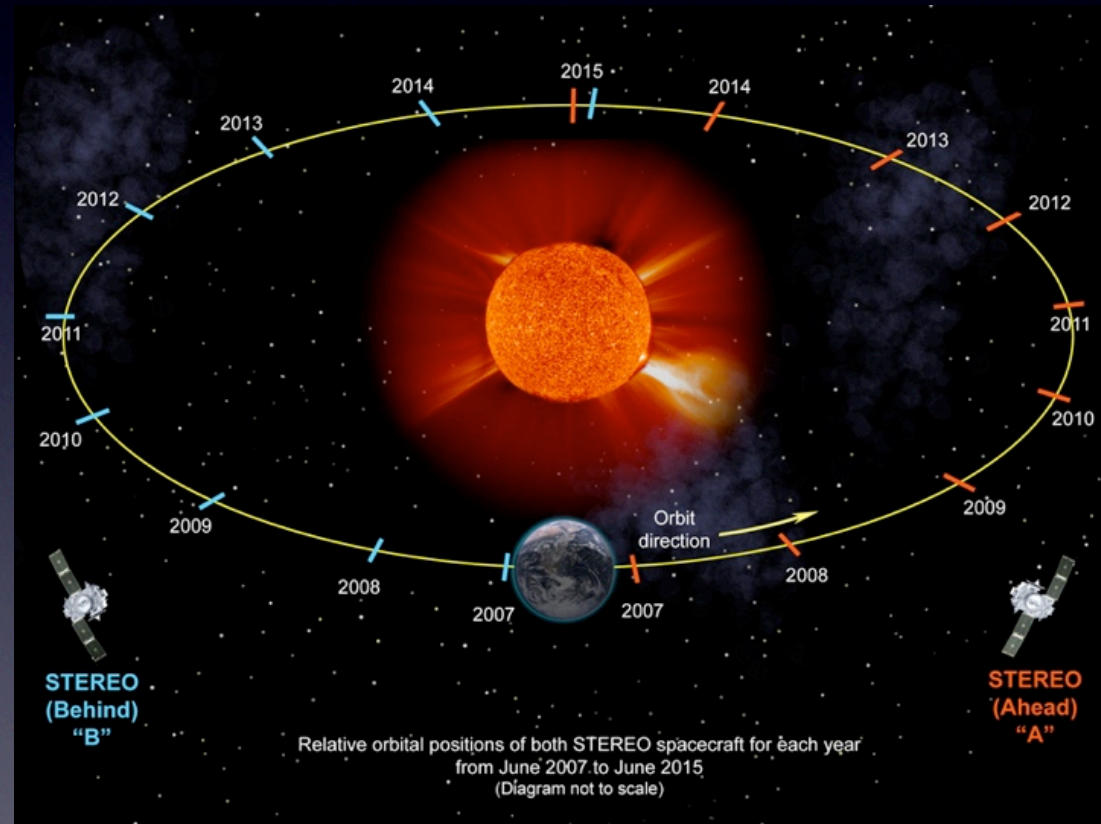




# *How long can we keep this up?*

Spacecraft will pass one another on the far side of the Sun in 2015

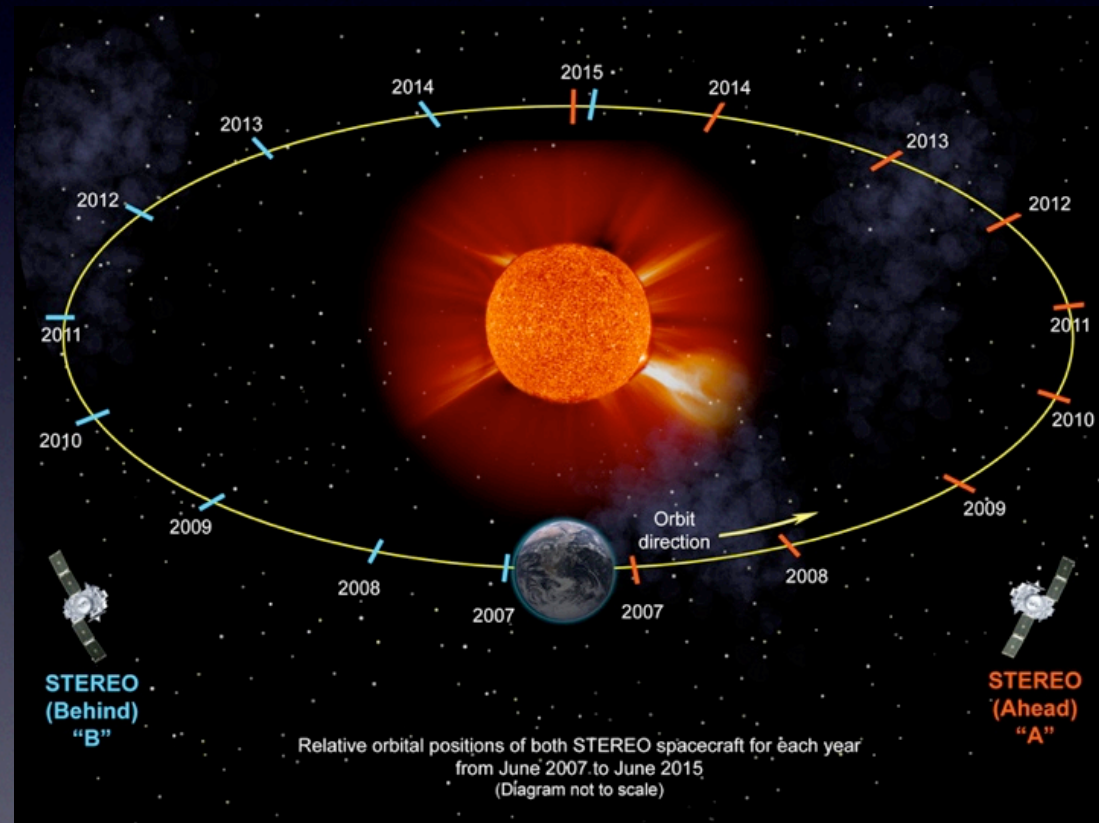
- Will need to rename them Aaft and Before, or something like that





# How long can we keep this up?

| Telemetry rate (kbps) | Date (Behind) | Date (Ahead) |
|-----------------------|---------------|--------------|
| 720                   | 2007/01/22    | 207/01/22    |
| 480                   | 2008/09/15    | 2008/10/13   |
| 360                   | 2009/09/08    | 2009/08/17   |
| 240                   | 2009/12/07    | 2010/04/26   |
| 120                   | 2010/11/15    | 2011/04/11   |
| 96                    | 2011/09/19    | 2011/09/26   |
| 60 (?)                | TBD           | TBD          |
| 30                    | 2012/08       | 2012/08      |







# *Beacon mode?*

- Beacon mode will need to switch to a different encoding scheme to maintain data rate with increasing distance
  - Will create issues with some receiving sites
  - Will work with NOAA SWPC to resolve
- Some receiving sites may not have sufficient link margin to obtain data from  $\sim 2$  AU



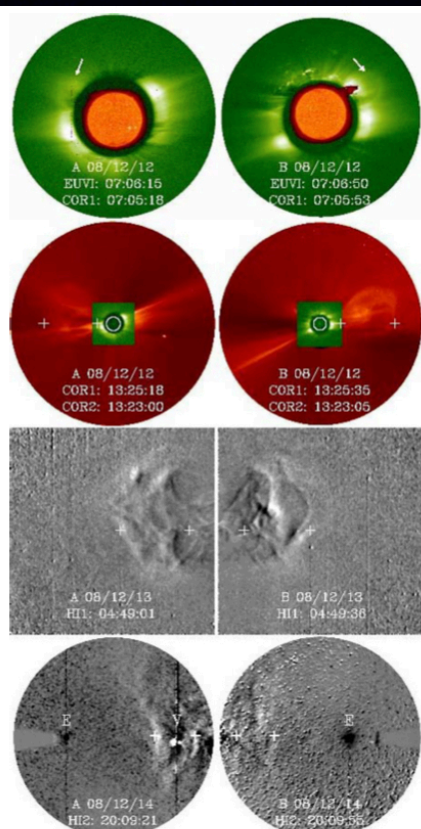
# *What have we learned?*

- We can model CME propagation
  - in 2 dimensions, geometrically
  - in 3 dimensions, using a forward model

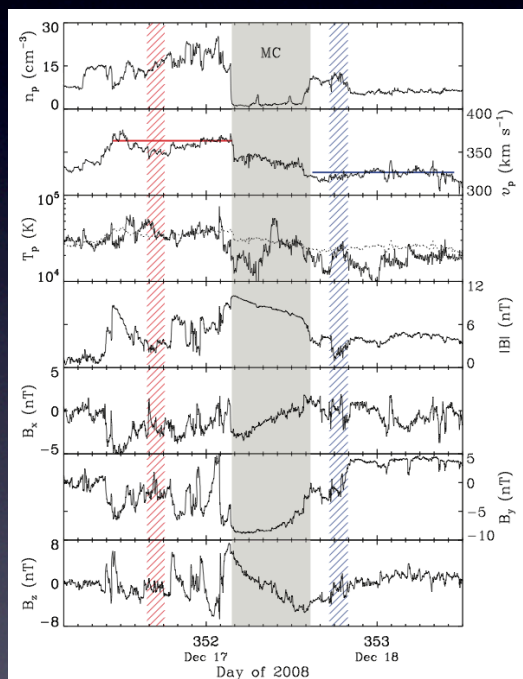




# Geometric triangulation using J-maps



**Figure 2.** CME evolution observed by STEREO A (left) and B (right) near simultaneously. From top to bottom, the panels display the composite images of EUVI at 304 Å and COR1 showing the nascent CME (indicated by the arrow), combined COR1 and COR2 images of the fully developed CME, and running difference images from HI1 and HI2 when the CME is far away from the Sun. The crosses mark the locations of the two features obtained from Figure 3. The positions of the Earth and Venus are labeled as E and V.

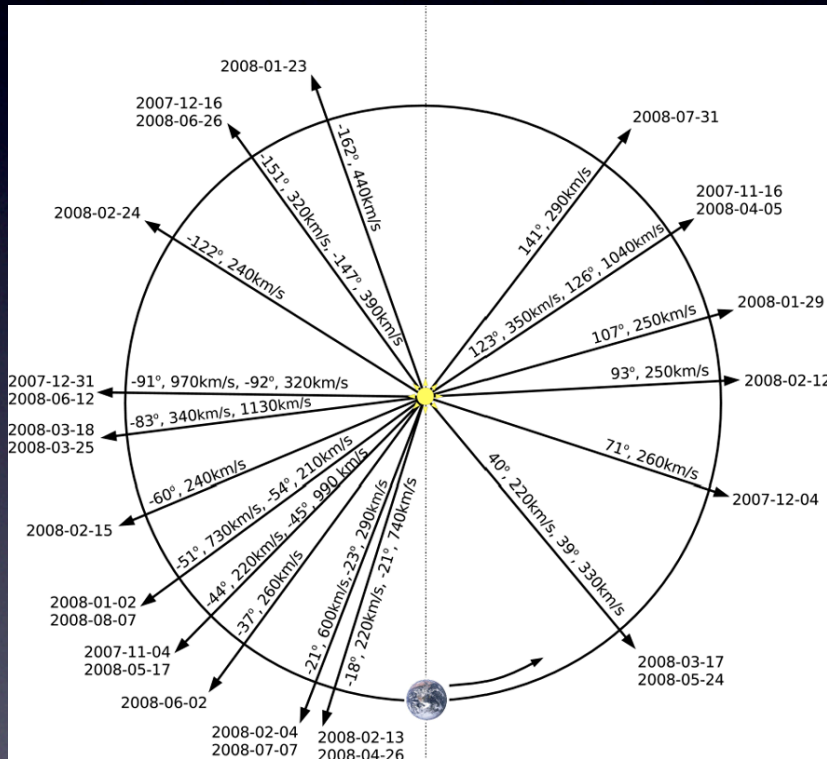


**Figure 5.** Solar wind plasma and magnetic field parameters across the MC observed at WIND. From top to bottom, the panels show the proton density, bulk speed, proton temperature, and magnetic field strength and components, respectively. The shaded region indicates the MC interval, and the hatched area shows the predicted arrival times (with uncertainties) of features 1 (red) and 2 (blue). The horizontal lines mark the corresponding predicted velocities at 1 AU. The dotted line denotes the expected proton temperature from the observed speed.

- *Liu et al. 2010, ApJ, 710, L82*
- *Able to predict speed, arrival time of at least two features in a CME*



# Forward modeling

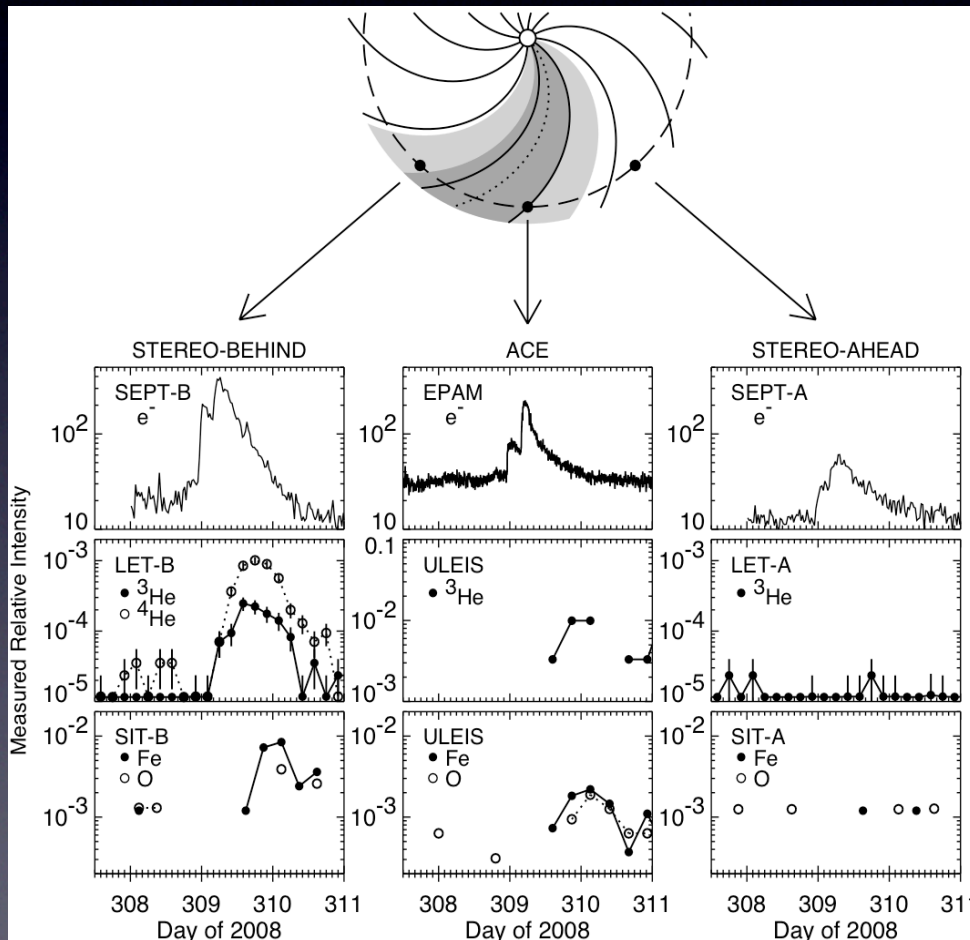


- Thernisien *et al.* 2009, Solar Phys., 256, 111
- Assume flux-rope geometry
- Works well for 17 events considered
- Implies that nearly all CMEs are flux ropes
- Can predict flux rope orientation → geoeffectiveness





# Angular extent of energetic particle events (I)

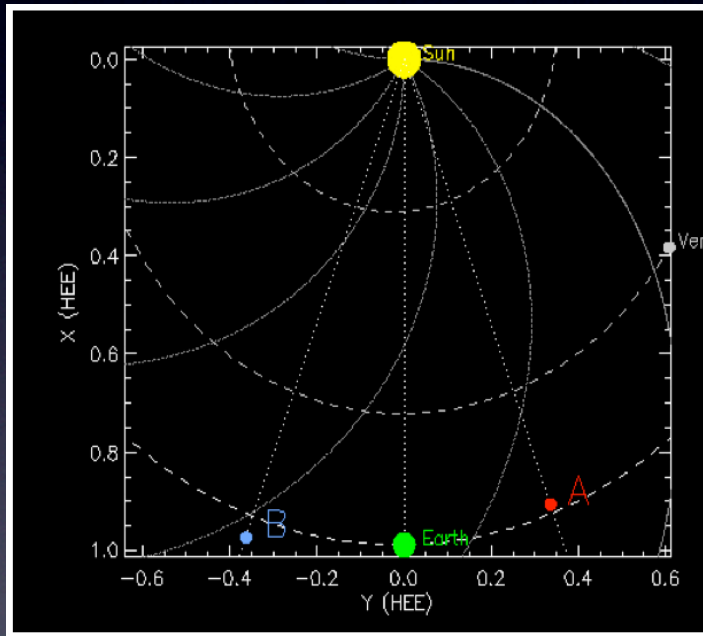


- Wiedenbeck *et al.* 2010, Proc. 12th Solar Wind Conf.
- STEREO A, B; ACE measurements show impulsive electron profile over  $> 80^\circ$  in heliolongitude
- 2010/02/12 event was visible when s/c were separated by  $> 130^\circ$



# Complexity of Magnetic Cloud field (CIR interaction)

- 2007 November 19 - 21



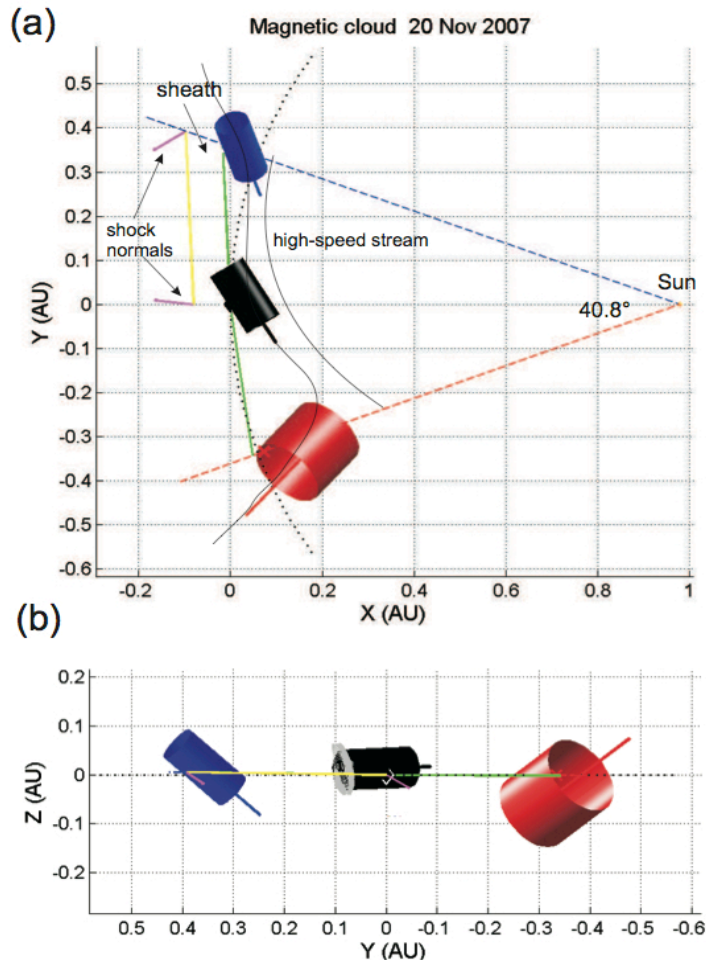
- Interaction of a CIR and a magnetic cloud near the heliospheric current sheet

- Farrugia *et al.* 2010, submitted to JASTP (special CME/ICME issue)
- “Double-dip” event in Dst (peak of -100 nT)





# Complexity of Magnetic Cloud field (CIR interaction)



- Reconstructions from three measurements (B, WIND, A) appear to show, from E to W, magnetic cloud:
  - after interaction with CIR
  - interacting with CIR, and
  - before interacting with CIR



*And I'm leaving out....*

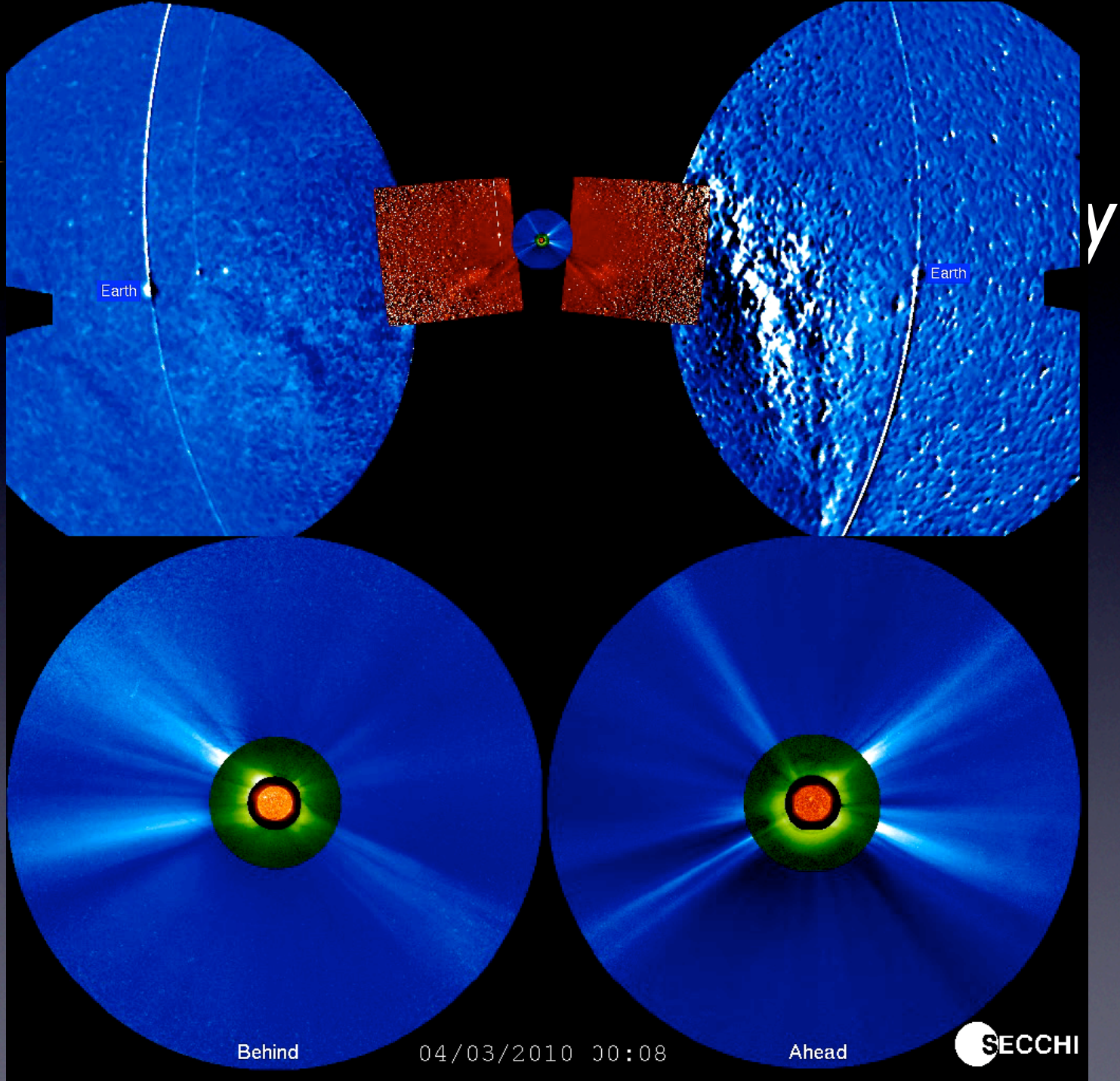
- Dust impacts
- High-amplitude whistler waves in solar wind halo electrons
- and about 300 other refereed journal articles





# *A Unique Set of Viewpoints on Solar and Heliospheric Activity*

Movie sequence from all four SECCHI telescopes  
on both STEREO spacecraft  
2010 April 3 - 12









# *Full-resolution telemetry*

- Acquired through Deep Space Network sites only
- Reformatted and available online in ~ 2 days
  - Longer for some higher level data products
- Available from the STEREO Science Center:
  - <http://stereo-ssc.nascom.nasa.gov/data.shtml>
  - Includes “instrument resource pages” link





# STEREO data

- Instrument resource pages
- Anonymous ftp access
- Data at PI institutions and elsewhere
- Access via virtual observatories
- Ancillary data

STEREO - Data

http://stereo-ssc.nascom.nasa.gov/data.shtml

STEREO SCIENCE CENTER

S S C

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comets, etc.

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links

**Archived Data**

- [Instrument resource pages](#)
- [Instrument data pages](#)
- [Instrument data archived at SSC](#)
- Alternative [anonymous ftp](#) access
- Virtual observatories / Data Centers
  - [Virtual Solar Observatory \(VS0\)](#)
  - [Virtual Space Physics Observatory \(VSPO\)](#)
  - [Virtual Heliospheric Observatory \(VHO\)](#)
  - [Coordinated Data Analysis Web \(CDAWeb\)](#)
- [Event lists](#)
- External browse tools
  - Solar Data Analysis Center [Solar Monitor](#)
  - [Solar Weather Browser](#)
  - [Integrated Space Weather Analysis System](#)
  - [Solar & Heliospheric Monitor](#)
- Mirror sites
  - [UK Solar System Data Centre](#), UK/Europe (SECCHI-only)
  - [IAS Data Center](#), Europe (SECCHI-only)
- [Ancillary data](#) (MOC data products)
- [Auxiliary data](#) (links to non-STEREO data)
- [Telemetry data](#)
- Space Weather Beacon
  - [Latest SECCHI beacon images](#)
  - [Plots of in-situ and radio beacon data](#)
  - [Beacon data files](#)
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# A sample “instrument resource” page (SECCHI)

- File contents description
- User’s guide
- Contact info

SECCHI – Solar Physics Branch – Naval Research Laboratory

http://secchi.nrl.navy.mil/index.php?p=SECCHI\_resource

Apple science News (22) STEREO SDAC NASA SDO SOHO Hinode stores Mac resources IFMP mishegas VSO

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[Latest beacon images](#)  
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[CME Queries](#)  
[Spacecraft](#)

**SECCHI Resource Page:**

- [Instrument descriptions](#)
- DATA
  - [SECCHI Data Management Plan \(pdf\)](#)
  - [Data Format \(FITS\) Description](#)
  - [Browse Images](#)
  - [Image Database Query](#)
- Software (For more details and the latest information, please visit the [SECCHI Wiki](#).)
  - [SECCHI Data Usage HOW-TO Guide](#)
  - [FESTIVAL](#) (SECCHI and EIT/LASCO FITS data display & manipulation)
  - Solar Corona Ray-Tracing Software
    - [User's Guide](#)
    - [Doxygen Code Documentation](#)
    - [Download Tarball Source Package](#)
  - Solar Feature and Event Detection and Displaying
    - [Solar Weather Browser](#) (Quicklook browser for displaying data)
    - [CACTus](#) (Automated CME detection)
    - [NEMO](#) (Automated EIT wave detection)
- [Reference Library](#) (goes to SECCHI wiki)
- Contact Information
  - [SECCHI Librarian](#)
  - [Mailing Lists](#)

Edited 6/27/08 by NR